

**CLAIMS:**

1. A method for joining a pipe having a first surface to an object having a second surface comprising the steps of:

(i) applying an effective amount of a curable one or two part adhesive composition to the first surface of the pipe, the second surface of the object or to both surfaces, wherein the adhesive comprises

(a) a boron containing initiator compound,

(b) one or more monomers, oligomers, polymers or mixtures thereof having olefinic unsaturation which is capable of polymerization by free radical polymerization, and

(c) optionally a decomplexing agent and

(ii) joining the first surface of the pipe with the second surface of the object.

2. The method of Claim 1 wherein the object is a fitting.

3. The method of Claim 2 wherein the pipe comprises a spigot having an exterior surface and the fitting comprises a bell having an interior surface and an open end for receiving the spigot whereby

(i) the curable adhesive composition is applied to the exterior surface of the spigot, the interior surface of the bell or to both surfaces and

(ii) the fitting and pipe are joined by inserting the spigot into the bell.

4. The method of Claim 1 wherein the pipe and the object independently comprise a metal, a multilayer plastic, a multilayer composite, a thermoplastic, a thermoset; or combinations thereof.

5. The method of Claim 1 wherein the pipe and object are thermoplastic.

6. The method of Claim 1 wherein the pipe and the object independently comprise a polyolefin; acrylonitrile, butadiene and styrene terpolymer; polyvinyl chloride; chlorinated polyvinyl chloride; or blends thereof.

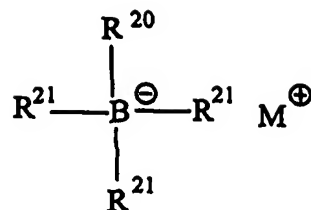
7. The method of Claim 1 where in the pipe and the object comprise polypropylene.

8. The method of Claim 1 wherein the pipe and the object comprise polyethylene.

9. The method of Claim 1 wherein the pipe is a first thermoplastic and the object is a second thermoplastic different from the first thermoplastic.

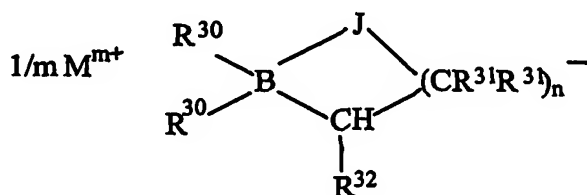
10. The method of Claim 1 wherein the boron containing initiator compound (a) comprises at least one of:

(a i) an organoborate having the following structure:

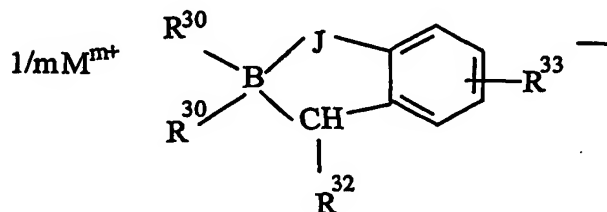


wherein B represents boron;  $\text{R}^{20}$  is  $\text{C}_1\text{-C}_{10}$  alkyl;  $\text{R}^{21}$  is independently in each occurrence  $\text{C}_1\text{-C}_{10}$  alkyl,  $\text{C}_3\text{-C}_{10}$  cycloalkyl, phenyl, phenyl-substituted  $\text{C}_1\text{-C}_{10}$  alkyl or phenyl substituted  $\text{C}_3\text{-C}_{10}$  cycloalkyl, provided that any two of  $\text{R}^{20}$  and/or  $\text{R}^{21}$  may optionally be part of a carbocyclic ring; and  $\text{M}^+$  is a metal ion or a quaternary ammonium ion,

(a ii) an internally blocked borate having the following structure:

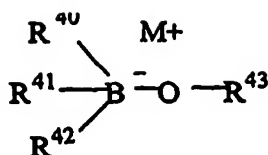


or



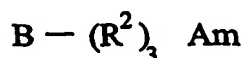
wherein B represents boron; J is oxygen or sulfur; when J represents oxygen, n is the integer 2, 3, 4 or 5; when J represents sulfur, n is the integer 1, 2, 3, 4 or 5;  $\text{R}^{30}$ ,  $\text{R}^{31}$ ,  $\text{R}^{32}$  and  $\text{R}^{33}$  are independently, substituted or unsubstituted alkyl or alkylene groups containing 1 to 10 carbon atoms, substituted aryl groups having up to 7 to 12 carbon atoms or unsubstituted aryl groups;  $\text{R}^{31}$ ,  $\text{R}^{32}$  and  $\text{R}^{33}$  can be hydrogen;  $\text{R}^{30}$  can be part of a second unsubstituted or substituted cyclic borate;  $\text{R}^{30}$  can comprise a spiro ring or a spiro-ether ring;  $\text{R}^{30}$  together with  $\text{R}^{31}$  can be linked to form a cycloaliphatic ring; or  $\text{R}^{30}$  together with  $\text{R}^{31}$  can comprise a cyclic ether ring and M is any positively charged species; with m being greater than 0,

(a iii) a hydroxide/alkoxide organoborane initiator having the following structure:



wherein B represents boron;  $R^{40}$ ,  $R^{41}$ , and  $R^{42}$  independently are alkyl groups having 1 to 10 carbon atoms and phenyl containing groups;  $R^{43}$  is a hydrogen or an organic group;  $M^+$  represents a monovalent cation such as a Group IA metal cation or onium or a multivalent cation, such as a Group IIA metal, and

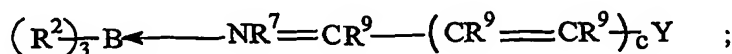
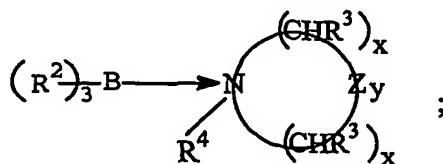
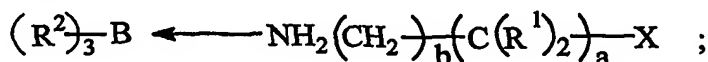
(a iv) an organoborane amine complex having the following structure:

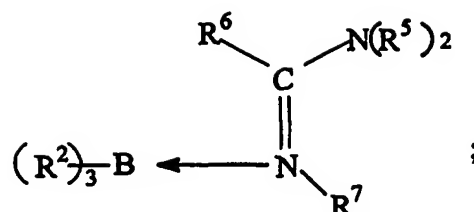


wherein B represents boron; and  $R^2$  is separately in each occurrence a C1-10 alkyl, C3-10 cycloalkyl, or two or more of  $R^2$  may combine to form a cycloaliphatic ring; and Am is an amine.

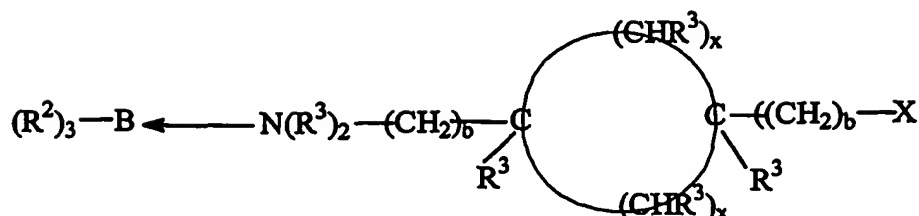
11. The method of Claim 10 wherein the amine in the organoborane amine complex (a iv) is a primary amine; a secondary amine; a polyamine having primary or secondary amines or both; ammonia; polyoxyalkylene amines; the reaction product of a diamine and a difunctional compound having moieties which react with an amine, wherein the reaction product has terminal amine groups; aryl amines; heterocyclic amines; a compound having an amidine structural component; aliphatic heterocycles having at least one secondary nitrogen in the heterocyclic ring wherein the heterocyclic compound may also contain one or more additional secondary or tertiary nitrogen atoms, oxygen atoms, sulfur atoms, or double bonds in the heterocycle; alicyclic compounds having bound to the alicyclic ring one or more substituents containing an amine moiety; conjugated imines or a mixture thereof.

12. The method of Claim 1 wherein the boron containing initiator compound comprises an organoborane amine complex having the structure





or



wherein

B is boron;

- 5  $\text{R}^1$  is separately in each occurrence hydrogen, a  $\text{C}_{1-10}$  alkyl or  $\text{C}_{3-10}$  cycloalkyl;  
 $\text{R}^2$  is separately in each occurrence a  $\text{C}_{1-10}$  alkyl,  $\text{C}_{3-10}$  cycloalkyl or two or more of  $\text{R}^2$  may combine to form a cycloaliphatic ring structure;  
 $\text{R}^3$  is separately in each occurrence hydrogen, a  $\text{C}_{1-10}$  alkyl,  $\text{C}_{3-10}$  cycloalkyl or forms a double bond with a  $\text{R}^3$  or  $\text{R}^4$  on an adjacent atom;
- 10  $\text{R}^4$  is separately in each occurrence hydrogen,  $\text{C}_{1-10}$  alkyl,  $\text{C}_{3-10}$  cycloalkyl,  $\text{C}_{6-10}$  aryl or  $\text{C}_{6-10}$  alkaryl;  
 $\text{R}^5$  and  $\text{R}^6$  are separately in each occurrence hydrogen,  $\text{C}_{1-10}$  alkyl,  $\text{C}_{3-10}$  cycloalkyl,  $\text{N(R}^4\text{)}_2$  wherein  $\text{R}^7$  is separately in each occurrence hydrogen,  $\text{C}_{1-10}$  alkyl,  $\text{C}_{3-10}$  cycloalkyl or two or more of  $\text{R}^5$ ,  $\text{R}^6$  and  $\text{R}^7$  in any combination can combine to form a ring structure which can
- 15 be a single ring or a multiple ring structure and the ring structure can include one or more of nitrogen, oxygen or unsaturation in the ring structure;  
 $\text{R}^9$  is independently in each occurrence hydrogen,  $\text{C}_{1-10}$  alkyl or  $\text{C}_{3-10}$  cycloalkyl, Y,  $\text{---(C(R}^9\text{)}_2\text{---(CR}^9\text{=CR}^9\text{)}_c\text{---Y)}$  or two or more of  $\text{R}^9$  can combine to form a ring structure, or one or more of  $\text{R}^9$  can form a ring structure with Y provided the ring structure is conjugated with
- 20 respect to the double bond of the imine nitrogen;  
 $\text{R}^{10}$  is separately in each occurrence  $\text{C}_{1-10}$  alkyl,  $\text{C}_{3-10}$  cycloalkyl or  $\text{---(C(R}^1\text{)}_2\text{)}_d\text{---W}$ ;  
W is separately in each occurrence hydrogen,  $\text{C}_{1-10}$  alkyl or X;  
X is  $\text{OR}^{10}$ ,  $\text{SR}^{10}$  or a halogen;

Y is independently in each occurrence hydrogen,  $\text{SR}^4$ ,  $\text{N}(\text{R}^4)_2$ ,  $\text{OR}^4$ ,  $\text{C}(\text{O})\text{OR}^4$ , a halogen or an alkylene group which forms a cyclic ring with  $\text{R}^7$  or  $\text{R}^9$ ;

Z is separately in each occurrence oxygen or  $-\text{NR}^4$ ;

a is separately in each occurrence an integer of from about 1 to about 10;

5 b is separately in each occurrence 0 or 1, with the proviso that the sum of a and b should be from about 2 to about 10;

c is separately in each occurrence an integer of from about 1 to about 10;

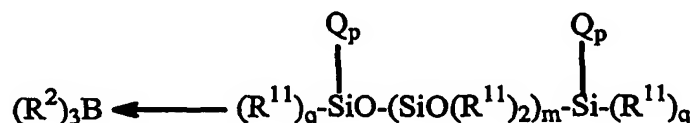
d is separately in each occurrence an integer of about 1 to about 4;

10 x is separately in each occurrence an integer of about 1 to about 10, with the proviso that the total of all occurrences of x is from about 2 to about 10; and  
y is separately in each occurrence 0 or 1.

13. The method of Claim 1 wherein the boron containing initiator compound comprises an organoborane amine complex having the structure



or



wherein

20 B represents boron;

$\text{R}^2$  is separately in each occurrence  $\text{C}_{1-10}$  alkyl,

$\text{C}_{3-10}$  cycloalkyl, or two or more of  $\text{R}^2$  may combine to form a cycloaliphatic ring;

Q is a hydrolyzable moiety;

25  $\text{R}^{11}$  is independently in each occurrence hydrogen, alkyl, alkoxy, alkenyl, alkyl amino or corresponds to the formula  $((\text{CR}^{14}\text{H})_r\text{O})_n-(\text{NR}^4)-(\text{CH}_2)_o-\text{NH}_2$  with the proviso that at least  $(\text{R}^{11})'$  is a primary amine leave this as is;

$\text{R}^{12}$  is independently in each occurrence hydrogen, alkyl, aryl, alkoxy, and may further contain one or more primary, secondary or tertiary amines;

$\text{R}^{14}$  is separately in each occurrence hydrogen or alkyl;

30  $\text{R}^4$  is hydrogen,  $\text{C}_{1-10}$  alkyl,  $\text{C}_{6-10}$  aryl or  $\text{C}_{7-10}$  alkaryl;

a is a number of form 1 to 10;

b is a number of form 0 to 1;

m is separately in each occurrence a whole number of 1 or greater;

p is separately in each occurrence a number of from 1 to 3;

5 q is separately in each occurrence an integer from 1 to 2 wherein the sum of p and q on each silicon atom is 3;

n is separately in each occurrence an integer of about 4 to about 400;

o is separately in each occurrence an integer of about 1 to about 9; and

r is separately in each occurrence an integer of 2 or 4.

10 14. The method of Claim 1 comprising a decomplexing agent selected from a Lewis acid, a Brønsted acid, an anhydride, an isocyanate, a sulfonic acid chloride, methacrylic acid, or an adduct of maleic anhydride and hydroxyethyl methacrylate.

15 15. The method of Claim 1 wherein the adhesive further comprises an effective amount of an isocyanate containing compound; one or more unpolymerized or partially polymerized compound having ring opening heterocyclic moieties and optionally a Lewis acid catalyst capable of initiating polymerization of the compound containing heterocyclic moieties; one or more compound, oligomer or prepolymer having siloxane groups and reactive moieties in its backbone capable of polymerization; one or more compound, oligomer or prepolymer having siloxane groups in its backbone which contain a moiety  
20 which when exposed to moisture forms an acid capable of decomplexing the organoborane amine complex; or mixtures thereof.

16. The method of Claim 1 wherein the adhesive comprises a polymerizable acrylate monomer.

25 17. The method of Claim 3 further comprising a gap for receiving the adhesive said gap is positioned between part or all of the mating exterior surface of the spigot and the interior surface of the bell.

18. The method of Claim 17 wherein the gap has a uniform thickness.

30 19. The method of Claim 18 wherein the gap comprises a channel in the bell, alignment guides raised from the interior surface of the bell which contact the exterior surface of the spigot, a guide ring fitted into an end of the bell said guide ring having a smaller internal diameter than the bell, a mesh collar of constant thickness, a gasket, a serrated washer, or combinations thereof.

20. The method of Claim 1 having a VOC emission of less than about 650 g/l.

21. The method of Claim 1 having a VOC emission of less than about 270 g/l.

22. A method to repair a new or existing pipe, object, or pipe/object joint having one or more surface in need of repair comprising the steps of

(i) applying an effective amount of a curable one or two part adhesive  
5 composition to the surface(s) in need of repair, wherein the adhesive comprises

(a) a boron containing initiator compound,

(b) one or more monomers, oligomers, polymers or mixtures thereof  
having olefinic unsaturation which is capable of polymerization by free  
radical polymerization,

10 and

(c) optionally a decomplexing agent and

(ii) bonding a repair patch to the surface in need of repair.